

**Claimed Subject Matter**

Claim 1 recites a method of etching openings in a dielectric layer with profile control, comprising (i) supporting a semiconductor substrate in a plasma etch reactor, the substrate including a dielectric layer; (ii) supplying an etchant gas to the plasma etch reactor; and (iii) etching openings in the dielectric layer by energizing the etchant gas into a plasma state, *the etchant gas comprising  $C_xF_yH_z$  wherein  $x \geq 1$ ,  $y \geq 1$  and  $z \geq 0$ ,  $SO_2$  gas and an oxygen-containing gas*, the  $SO_2$  gas and the oxygen-containing gas being added in amounts *effective for profile control* of the etched openings. The combination of features recited in Claim 1 is not suggested by Yang, Bobbio and Khajehpour.

**Yang Teaches Away from Oxidizing Component in the Etch Gas**

Yang discloses the addition of first and optionally second (hydro)fluorocarbon gases such as  $c-C_4F_8$  to "an etching gas" to enhance selectivity of oxide etching over nitride etching (column 2, lines 16-54 of Yang). The "etching gas" to which the first and second (hydro)fluorocarbon gases are added include various gases such as  $CHF_3$  (column 2, lines 62-67 of Yang). Yang does not include  $SO_2$  and oxidizing gases in the list of suitable etch gases. Yang explicitly teaches away from incorporating oxidizing gases in the etch gas by stating that CO, if formed during etching, should "not be added" and even if present should be below 5 vol. %, preferably below 0.001 vol. % (column 3, lines 13-17 of Yang). Accordingly, any modification of Yang to include an oxygen-containing gas would go against Yang's teachings since such oxygen-containing gas would form undesirable CO due to reaction with C in the photoresist.

**Unobvious to Add Oxidizing Component of Bobbio to Yang  
Because Yang and Bobbio Seek Selectivity for Unrelated Materials**

The oxides to be etched in Yang and Bobbio are located above unrelated materials and the etch gases of Yang and Bobbio are tailored to achieve selectivities with respect to these unrelated materials. In particular, Yang seeks selectivity with respect to nitride whereas Bobbio seeks selectivity with respect to polysilicon or silicon. Thus, the teachings of Bobbio relating to polysilicon or silicon selectivity have no application to Yang's etch process.

Bobbio discloses use of  $\text{SO}_2$  or other oxidizing components such as  $\text{CO}_2$ ,  $\text{O}_2$ ,  $\text{NO}$  or  $\text{H}_2\text{O}$  to a  $\text{SF}_6$  and nitrogen containing compound gas mixture to provide faster etching of  $\text{SiO}_2$  relative to  $\text{Si}$  or polysilicon (column 2, lines 5-17 of Bobbio). Bobbio does not seek to etch oxide with selectivity to nitride as in Yang. Instead, Bobbio relates to a  $\text{SF}_6/\text{NH}_3$  system to which oxidizing  $\text{NO}$ ,  $\text{SO}_2$ ,  $\text{H}_2\text{O}$ ,  $\text{O}_2$  or  $\text{CO}_2$  is added for improving selectivity of an oxide etch to underlying silicon or polysilicon (column 3, lines 4-31 of Bobbio). Because Yang and Bobbio seek to etch oxide with selectivity to different and unrelated materials (nitride in Yang versus silicon or polysilicon in Bobbio), there is no basis for the assumption in the Official Action that the oxidizing component of Bobbio could be added to Yang "to enhance selectivity of the oxide" (Official Action at page 2).

**The Improper Combination of Yang  
and Bobbio Cannot be Remedied by Khajehanouri**

As explained above, Yang and Bobbio seek to etch silicon oxide with selectivity to different and unrelated underlying materials making the teachings of Bobbio unsuitable for incorporation in Yang. Bobbio's teachings to add oxidizing  $\text{NO}$ ,  $\text{SO}_2$ ,  $\text{H}_2\text{O}$ ,  $\text{O}_2$  or  $\text{CO}_2$

to an  $\text{SF}_6/\text{NH}_3$  etch system provides no motivation to selectively add only Bobbio's oxidizing component to Yang's completely different etch gas mixture. Because Yang seeks to obtain selectivity with respect to a nitride underlayer, a material not mentioned in Bobbio, Bobbio and Yang are improperly combined in the Official Action. The further addition of Khajehanouri cannot remedy this improper combination of references.

As discussed on page 2 of the present application, Khajehanouri describes etching of openings in silicon oxide layers using a gas mixture of fluorocarbon, oxygen and nitrogen wherein the *oxygen and nitrogen are added in amounts to control the profile* of the etched opening. There is no basis for the allegation in the Official Action that "one skilled in the art would find it obvious to control the amount of the etching components such as  $\text{O}_2$  and  $\text{SO}_2$  (sulfur-containing gas) in order to control the profile [of] the etched openings" (Official Action at page 2). Khajehanouri discloses that "oxygen removes polymer by forming CO" (column 4, lines 14-15 of Khajehanouri) whereas *Yang seeks to eliminate CO* formed during the etching process (see column 3, lines 13-17 of Yang). The Official Action fails to set forth any tenable basis to support the rejection since there is no explanation as to why a person of ordinary skill in the art would have been motivated to modify Yang in a manner which goes against the teachings of Yang.

#### **Unexpected Results**

The prior art references applied against the claims fail to recognize the surprising effect of  $\text{SO}_2$  and an oxygen-containing gas in providing profile control, i.e., straight or tapered openings (see paragraph 0019 on pages 8-9 of specification). As explained in the present application, as the dielectric layer is etched with fluorine containing species and C

forms a protective polymer in sidewalls of etched openings, the oxygen and sulfur dioxide cooperate to balance polymer build-up sufficiently to protect sidewalls of etched features while avoiding pinch-off and etch stop problems (see paragraph 0030). Figure 1 shows how "bowing" can occur when etching with only O<sub>2</sub> whereas addition of SO<sub>2</sub> can surprisingly provide the "tapered" profile in Figure 2 or the "straight" profile in Figure 3 (see paragraph 0036). Such results are unexpected in view of Yang and Bobbio wherein profile control is not even mentioned. While Khajehanouri discloses use of oxygen and nitrogen to obtain profile control, there is no suggestion in Khajehanouri of using O<sub>2</sub> in combination with SO<sub>2</sub> to achieve profile control. The surprising ability of the claimed process to achieve desired tapered and straight profiles using oxygen and SO<sub>2</sub> clearly rebuts any *prima facie* case of obviousness based on the combination of Yang, Bobbio and Khajehanouri.

### Conclusion

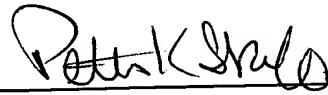
It is submitted that the differences between the claimed subject matter and the prior art are such that the claimed subject matter, as a whole, would not have been obvious at the time the invention was made to a person having ordinary skill in the art.

Application No. 09/883,207  
Attorney's Docket No. 015290-504

In view of the foregoing, it is submitted that the present application is in condition  
for allowance and such action is earnestly solicited.

Respectfully submitted,

BURNS, DOANE, SWECKER & MATHIS, L.L.P.

By:   
Peter K. Skiff  
Registration No. 31,917

P.O. Box 1404  
Alexandria, Virginia 22313-1404  
(703) 836-6620

Date: August 12, 2003